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Thermal Pollution Control
In Massachusetts Coastal Waters

Water Resources Commission
Division Of Water Pollution Control
Thomas C. Mc Mahon, Director

THERMAL POLLUTION CONTROL IN MASSACHUSETTS COASTAL WATERS

BY

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BOSTON
APRIL 1972
JANUARY 1973

Publication No. 6505 (16-400-12-72-CR)
Approved by Alfred C. Holland, Purchasing Agent

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BY

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The Massachusetts Water Quality Standards, which were adopted in March, 1967, include parameters for temperature as shown in Figure 1. No numerical limits were established for temperature in marine waters, but rather, the standards state that the allowable temperature increase shall be:

> "None except where the increase will not exceed the recommended limits on the most sensitive water use."

Therefore, control of heated water discharges into these waters was predicated on long term, before-and-after hydrothermal and biological studies for each installation which would determine the most sensitive use and the recommended temperature limits. The results of these studies could than be used to establish temperature limits for the specific discharge in question.

The objective of this paper is to review approximately four years of experience in this approach to thermal pollution control by briefly examining specific cases and describing: (1) the scope of the studies performed or planned for each installation, and (2) the methods of control used or proposed for the heated water discharges.

Figure 2 summarizes the electric generating plant installations discussed. Two installation, including one nuclear plant involved new site developments, and three are expansions or new units at existing sites. All plants use salt water

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This paper was presented at the Fall meeting of the New England Water Pollution Control Association, Newport, Rhode Island, October 26-28, 1971

FIGURE 2

SUMMARY OF RECENT ELECTRIC GENERATING STATION INSTALLATIONS

Name of Plant	Generating Capacity MW		Circulating Water Quantity gpm	Temp Rise F	Date of Start-Up	Discharge To	Hydrothermal - Biological Studies	
	Addn	Total					Duration	To Be Completed
Canal Plant (Canal Electric Co.)	---	560	167,000	26	1968	Cape Cod Canal	4 years	1970
Salem Station (N.E. Power Co.)	475	780	470,000	17	1972	Salem Harbor	3 years	1974
Pilgrim Nuclear (Boston Edison)	---	650	311,000	29	1972	Cape Cod Bay	4 Years	1973
Brayton Point (N.E. Power)	475	1590	1,190,000	12	1973	Lee River (Mt. Hope Bay)	5 years	1975
Mystic Station (Boston Edison)	600	1200	630,000	20	1975	Mystic River (Boston Harbor)	3 years	1977

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for condenser circulating water. Three plants discharge to estuaries, one to the ocean (Cape Cod Bay) and one to Cape Cod Canal. The Division of Water Pollution Control has issued interim permits for new wastewater discharge outlets for the five plants in accordance with Section 43 of the Clean Waters Act (General Laws Chapter 21, amended).

CAPE COD CANAL PLANT

The Canal Plant, owned by the Canal Electric Company, is situated on the South bank of the Cape Cod Canal near its easterly terminus at Sandwich. The Canal is a unique situation for thermal discharge since tidal fluctuations cause an almost continual high velocity flow in one direction or the other. Since the tidal range is nine feet at Cape Cod Bay (Sandwich) and only four feet at Buzzards Bay or the westerly Canal terminus, two-thirds of the time (or eight hours of a twelve hour tidal cycle) flow is in the westerly direction. This is advantageous for the discharge of heated water since Cape Cod Bay water is colder than Buzzards Bay water by as much as 15°F.

The marine fishery, and specifically finfish, were assumed to be the most sensitive use of the canal waters as far as the temperature criterion is concerned. On this basis the temperature limits to be imposed on the heated water discharge were predicated on a two year ecological study which would include one year prior to operation of the plant and one year after operation. (Note: Since the Division of Water Pollution Control had not been established, the studies were requested by the Massachusetts Division of Marine Fisheries.) Due in part to plant start-up problems the study actually extended over a period of almost five years with 28 months covering pre-operation and 30 months covering post-operation.

The study was financed entirely by the power company at a cost of approximately $240,000 and was performed primarily by the Massachusetts Division of Marine Fisheries with some assistance by the Federal Bureau of Sport Fisheries and Wildlife Laboratory at Sandy Hook, New Jersey. The study included hydrography, distribution and occurences of fishes, fish eggs and larvae, and benthic flora and fauna. Techniques used in the study included scuba diving, test panels, sample plots and creel counts, along with continual monitoring of temperature and salinity.

An Administrative-Technical Advisory Committee composed of representatives of both State and Federal agencies having responsibilities for marine fisheries, and the Canal Electric Company was established to set guidelines and review results of the study. At the conclusion of the five year study the Committee made several recommendations which included a maximum discharge temperature limit of 86°F. The rationale for this temperature limit was based on a determination that the menhaden fishery was the most sensitive water use and 86°F was the recommended maximum permissible temperature for this species in this particular situation. A proposed second unit at this site will include a modification to the heated water discharge piping (most likely a submerged diffuser) which is being designed to meet this temperature standard.

SALEM HARBOR STATION

The Salem Harbor Station is owned and operated by the New England Power Company. The existing station has three generating units with a combined capacity of 340 MW. A fourth unit with a capacity of 475 MW is presently under construction. Two temperature studies were performed in May and August of 1968, by New England Power Company in connection with the proposed expansion which was scheduled for start-up in 1972. The studies were performed to determine the adequacy of cooling

water supply for a fourth unit and to determine the effect of the heated water discharge on water temperatures in Salem Harbor.

The studies showed relatively good mixing of the discharge with Harbor water and the discharge generally only affected Harbor water temperature within 10 feet of the surface over an area of slightly more than one square mile. Salem Harbor waters rarely exceed 65°F and the heated water discharge temperature during the survey did not exceed 78°F. The immediate entrainment of dilution water by the discharge and subsequent heat dissipation in the Harbor resulted in a low temperature increase in the receiving water (between 1 and 5 degrees F) over the affected area.

The power company proposed modifications to the discharge canal in connection with the expansion which would increase entrainment of dilution water and minimize recycling through the intake system. The Division of Water Pollution Control after consultation with the Division of Marine Fisheries limited the allowable temperature increase through the plant to 20°F above intake water temperature. The methods of control agreed to by the Company to attain compliance with this temperature limit were (1) the operation of circulating water pumps of idle generating units to supply dilution water when necessary to reduce the discharge temperature, and (2) breeching of the discharge canal to allow the inlet of larger quantities of dilution water (either by induced flow or pumping) if necessary.

Due to relatively low temperatures involved and considering the nature of the fishery no biological studies were performed as part of the pre-operational study and no requirements for post-operational studies were stipulated in the Division of Water Pollution Control permit. However, the power company has initiated an extensive three-year hydrothermal and ecological study which will cover one year of pre-operation and two years of post-operation of the fourth unit (presumably in connection with planning for additional generating capacity). The study will be performed by the Massachusetts Division of Marine Fisheries at a cost of approximately $385,000.

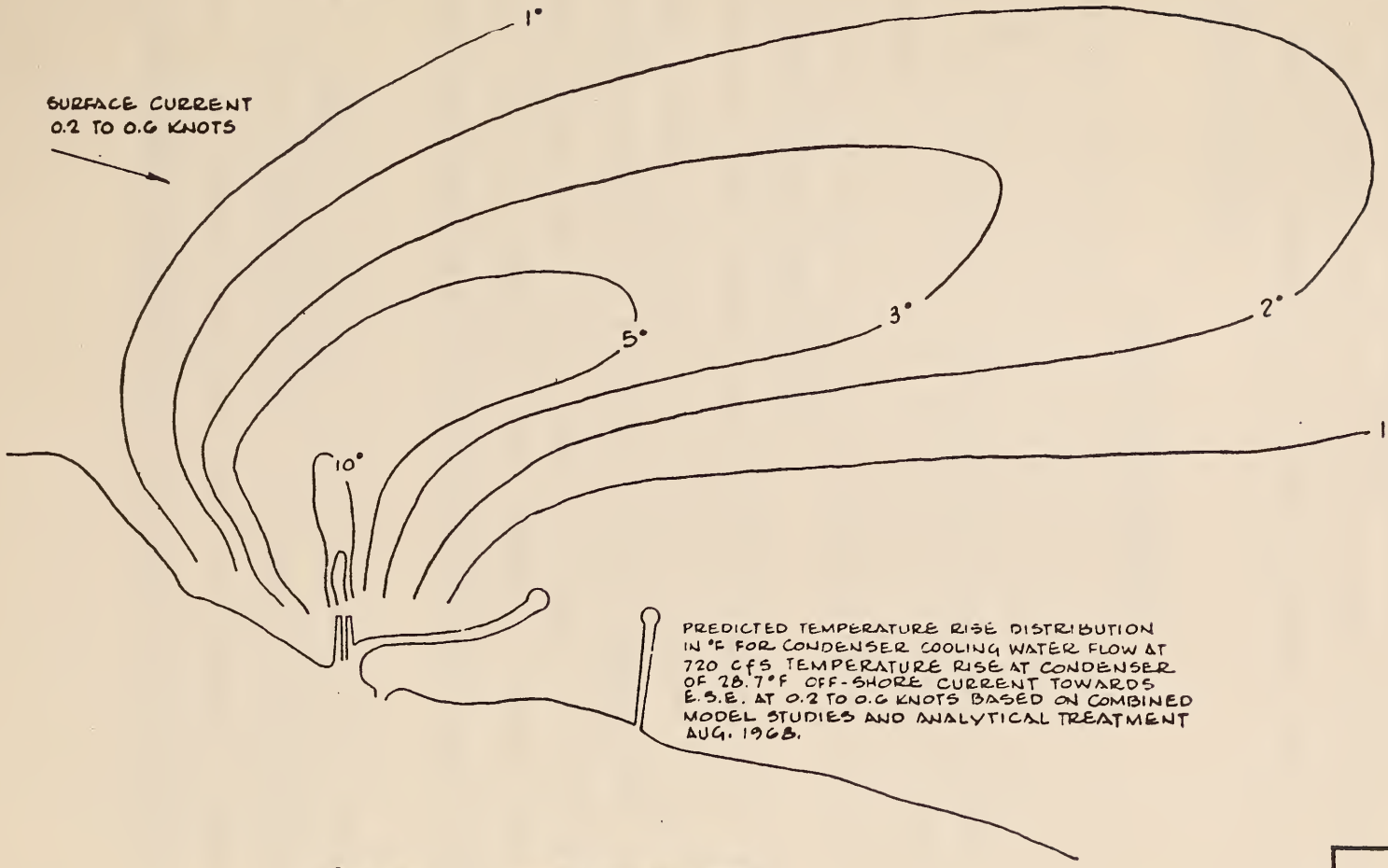
PILGRIM NUCLEAR STATION

The Pilgrim Nuclear Station (650 MW) under construction by Boston Edison Company is the first major nuclear plant in Massachusetts (the Yankee Atomic Plant in Rowe, built in 1963, has a capacity of 185 MW). Because of the many permits and approvals required from various State agencies particularly for a new site, Governor Volpe established an inter-agency ad hoc committee in 1969 to meet regularly with Boston Edison personnel concerning requirements for permits. Mr. Gerald Parker, Chief of the Radiological Health Unit of the Department of Public Health (presently the Bureau of Radiation Control) was appointed Chairman.

The power company performed extensive oceanographic studies including drogue and dye studies and the operation of an off-shore instrumentation station to monitor sea temperature and current velocity and direction. The studies were performed by Bechtel Corporation who engaged consultants from Wood Hole Oceanographic Institute (ecology), Chesapeake Bay Institute (oceanography), Worcester Polytechnic Institute (water front protection) Massachusetts Institute of Technology (coastal engineering), and New York University Medical Center (radiology).

A system of breakwaters were designed to separate intake and discharge flows and hydraulic models were constructed to study both the thermal dispersion (MIT) and the effects of wave action (Alden Laboratory). Figure 3 shows the predicted temperature dispersion for one hydrodynamic condition based on a combination of hydraulic model and mathematical analyses.

Following review of the report on the aforementioned studies an interim permit was issued to Boston Edison for construction and operation of the wastewater discharge outlet. A condition of the permit requires that the company make any modifications indicated as being necessary to protect human or aquatic life after completion of a two year post-operational study.



PILGRIM
NUCLEAR POWER STATION

Cooling Water Dispersion

FIGURE 3

The Boston Edison Company is paying the entire cost of four year pre-operational and post-operational hydrothermal, ecological and radiological studies (approximately $330,000). An Administrative-Technical Advisory Committee which includes representative of Federal and State agencies and the power company was established to oversee the studies and to make recommendations based on the results.

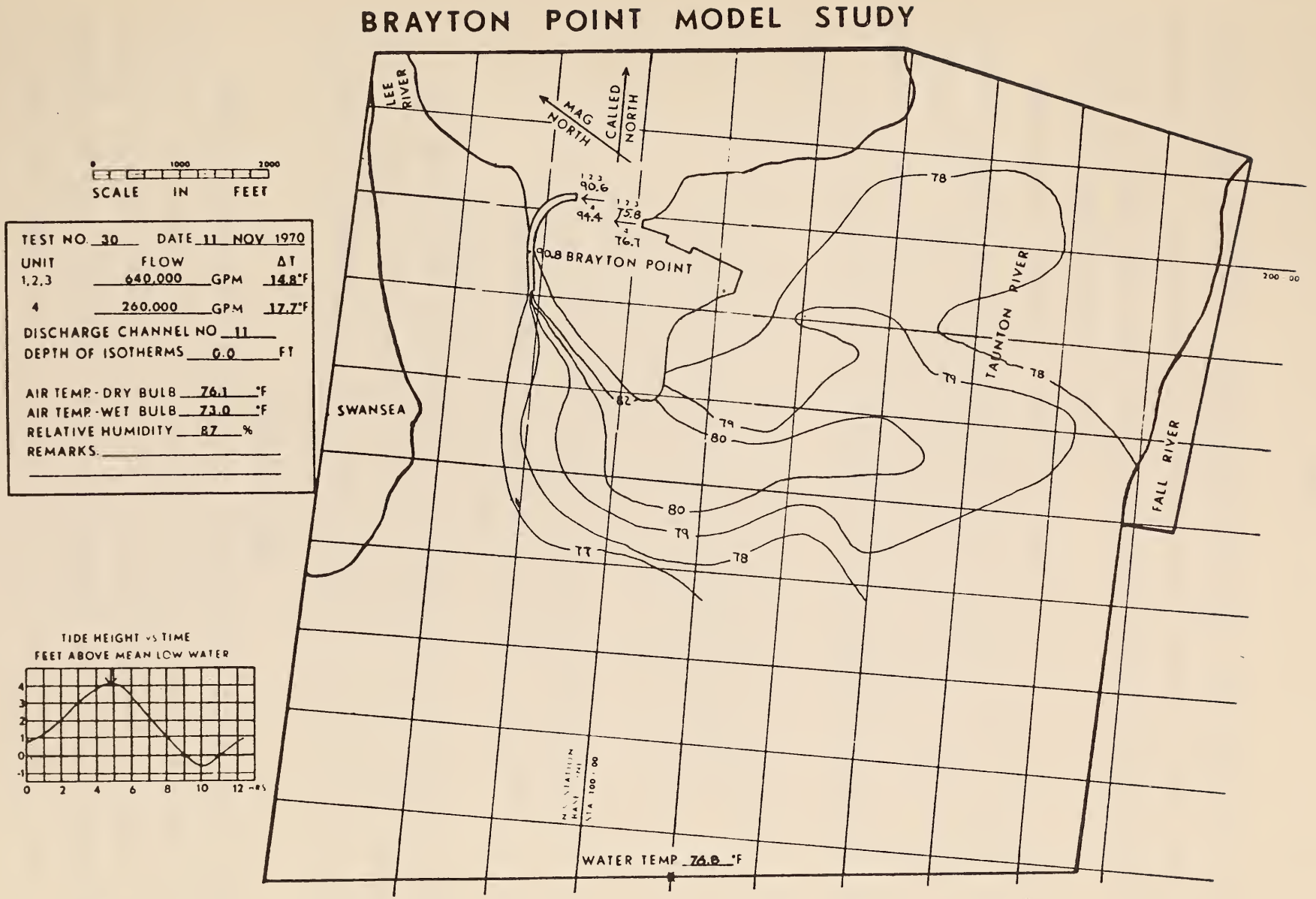
Field and laboratory studies are being performed by the Massachusetts Division of Marine Fisheries, Raytheon Marine Research Laboratory, Battelle Laboratory and ICN/Tracerlab (radiology).

BRAYTON POINT STATION

The Brayton Point Station located in Somerset at the North end of Mount Hope Bay (across the Bay from Fall River) is owned and operated by the New England Power Company. It is currently the largest generating plant in New England with an installed capacity of 1125 MW. The plant obtains its condenser circulating water from Taunton River side of Mount Hope Bay and discharges heated water into the Lee River near its mouth in upper Mount Hope Bay.

In connection with construction of a fourth generating unit of 475 MW capacity the Company proposed construction of an extended discharge canal which would: (1) divert the discharge away from the main body of the Lee River, and (2) employ a jet-type discharge which would entrain a large amount of dilution water to immediately reduce the temperature of the discharge. Figure 4 shows the predicted temperature dispersion from the proposed modified canal based on hydraulic model studies.

Due to complaints from Swansea residents concerning high temperatures (in excess of 90°F) at the Swansea beaches, and because of other wastewater disposal problems at the plant, the Division of Water Pollution Control issued an abatement order to the Company requiring (among other things) early construction of the



Recommended Discharge Channel. 4-Unit Operation. Surface Isotherms at High Water Slack

Figure 4

extended canal to serve the existing three-unit plant. This would also permit evaluation of an extended canal, and verification of hydraulic model predictions for the three-unit plant would provide a degree of confidence in the hydraulic model studies for the four unit plant.

Proceeding on this basis a permit was issued for the fourth unit with conditions for stringent control of the heated water discharge from the four-unit plant (1,190,000 gpm), and upon recommendation of the Division of Marine Fisheries, an interim temperature limit of 90°F was placed on the discharge at the canal exit.

To meet this temperature limitation the Company agreed to methods of control as follows:

(1) The introduction into the discharge canal of a quantity of dilution water equal to the quantity of condenser cooling water required for the fourth unit (approximately 280,000 gpm).

(2) A cut-back or curtailment of operation of the fourth generating unit when necessary to maintain a discharge temperature not to exceed 90°F.

Both the requested improvements to the existing plant and work on the additional control for the fourth unit have been suspended by the company pending issuance of a discharge permit by the Corps of Engineers under the 1899 Refuse Act.

MYSTIC STATION

Boston Edison's Mystic Station is located in Everett on the lower or tidal portion of the Mystic River. The existing plant has six generating units with a combined capacity of 600 MW. A fourth unit of 600 MW capacity is planned to be in operation by 1977. Due to the low water temperatures prevailing in Boston Harbor no significant thermal problem is anticipated due to the increased heat load. In

fact, the increased flow resulting from the additional circulating water requirement may improve water quality by providing flushing action of the tidal portion of the river which is dead-ended a short distance upstream at the Amelia Earheart Dam. Nevertheless, pre-operational and post-operational hydrothermal and biological studies were made a condition of the interim permit for the heated water discharge to determine the biological impact of the increased discharge.

CHLORINATION PRACTICE

Very early in the game it was recognized that the presence of chlorine in the condenser cooling water discharges from power plants could be more detrimental to marine aquatic life than the addition of heat. All of the plants discussed in this paper periodically add sodium hypochlorite to their circulating water systems to control the growth of bacterial slimes in the condenser tubes and other piping. Initially a requirement not to exceed a residual chlorine concentration of 0.7 mg/l in the discharge was imposed as a condition of the permits for power plant discharges.

Operating experience at the Canal Plant indicated that this level was much too high (at least for Cape Cod Canal and areas where Menhaden predominate) and the permissable residual level was lowered to 0.1 mg/l on subsequent permits. The 0.1 mg/l limit was established on the basis of bioassays on Menhaden which indicated a TL_m of 0.7 mg/l. Ten percent of that value (0.07 mg/l) was considered a safe concentration and this was rounded off to 0.1 mg/l as a practical measurable limit.

Research work now underway by the Environmental Protection Agency's National Marine Water Quality Laboratory indicates that present chlorination practices at power plants contribute to high mortalities among entrained plankton, particularly phytoplankton. The effect of these mortalities on the primary production and fisheries of the adjacent waters are being investigated.

The approach taken by the Division toward the use of hypochlorite has been to require adequate controls and continuous monitoring of residuals. This information correlated with results of pre-operational and post-operational biological studies will permit a fairly precise evaluation of the total biological effect of chlorination at a specific installation.

SUMMARY AND CONCLUSIONS

Our experience with the five plants discussed plus our involvement with several more which are in the planning stage or are located just outside our borders have resulted in certain standard procedures toward the issuance of permits for wastewater discharge from power plants. These can be summarized as follows:

(1) In every case a preliminary hydrothermal and ecological study of the receiving water including benthic studies must be accomplished before any serious consideration can be given to expanding an existing plant or developing a new site.

(2) Usually (but not always) a physical hydraulic model study is required to predict the dispersing pattern of the heated water discharges under varying conditions. This can sometimes be determined mathematically or by dye and drogue studies on existing discharges.

(3) When the Division and other State agencies which have affected responsibilities are satisfied that there will not be any significant adverse effects on the marine resources or other use of the water, an interim permit is issued, usually for a period of three years from the date of plant start-up.

(4) In most situations, a condition of the permit will require the power company to perform fairly long-term, before-and-after hydrothermal and ecological studies (usually two years before and two after) to determine the more subtle effects of the discharge and to afford some insight into possible long-term effects.

(5) Administrative-Technical Advisory Committees composed of representatives of Federal and State agencies and including the power companies and their consultants are established to coordinate the many groups involved, to insure that the studies are technically meaningful and to make recommendations to the permitting agencies at the completion of the study.

(6) Finally, a final permit is issued only after the modifications indicated as necessary from the long-term studies are made either to the facilities or to the method of operation.

We think that this is a reasonable, workable approach to a very complex problem. It has evolved from a fairly short, but intensive involvement with the problem of thermal discharges from power plants. The electric power industry, faced with greater and greater difficulties in developing new sites, is accepting the need for in-depth environmental studies for all future generating plant development. Even at this point in time the electric power industry has probably performed more water quality studies on receiving waters than the remaining industries combined. In final analysis they should be treated no better or worse than any industry having a wastewater disposal problem. They, like other industries must accept the fact that the cost of wastewater disposal is simply a part of the cost of producing a finished product, in this case electrical energy, and that protection of the environment is an essential part of their operation.